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PCT

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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : G10H 1/32, G10C 3/06 — A2

(11) International Publication Number: **WO 00/36586**

(43) International Publication Date: 22 June 2000 (22.06.00)

(21) International Application Number: PCT/GB99/04226

(22) International Filing Date: 14 December 1999 (14.12.99)

(30) Priority Data:

9827520.9	14 December 1998 (14.12.98)	GB
9904588.2	26 February 1999 (26.02.99)	GB
9905821.6	12 March 1999 (12.03.99)	GB

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(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

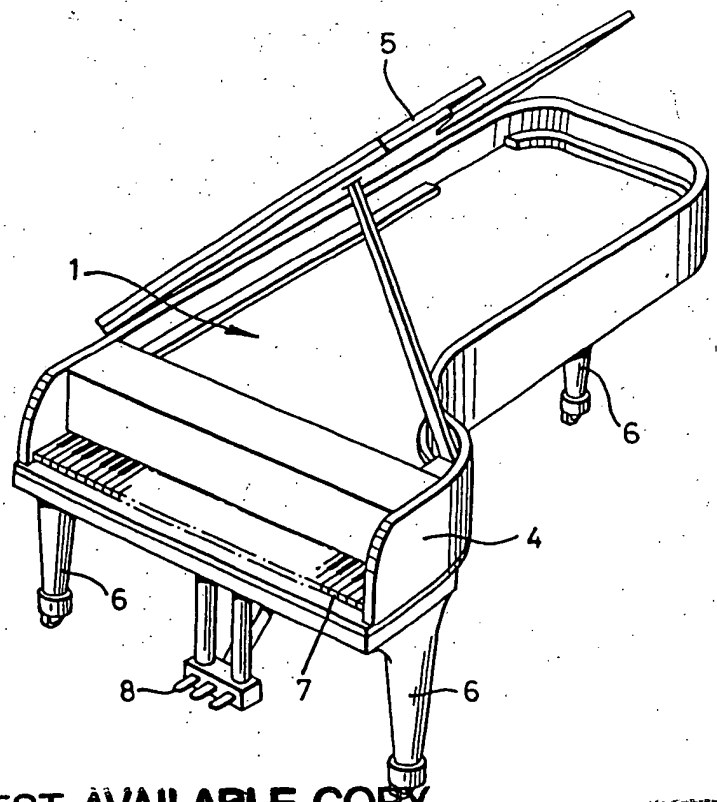
Published

Without international search report and to be republished upon receipt of that report.

(54) Title: ELECTRONIC PIANO

(57) Abstract

A digital piano having a sound output means comprising a panel (1) which is arranged to generate sound as a result of the inducement of resonant bending mode vibrations. The panel (1) being orientated within a casing (4) having the shape of a conventional grand piano casing. When a musician plays on the keys (7) of the piano a sound selected from a library of sounds and output through the panel (1) to generate air disturbance patterns which emulate the spatial characteristics of the sound generated by a conventional grand piano.



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ELECTRONIC PIANO

This invention relates to electronic keyboard instruments. In particular, this invention relates to electronic pianos.

In a conventional acoustic piano, when a key is depressed this causes a hammer to strike a string or strings whose vibrations generate a note. The pitch of the note is primarily dependent upon which string or strings are struck. However, the actual sound generated is determined by the interaction of structural features of the entire instrument and is dependent on factors including the materials from which the piano is made, the use of the foot pedals, the other strings which may be vibrating at the same time and exactly how the musician has pressed the key.

In a digital electronic piano, when the keys are depressed by a musician, this is detected and the signals generated are used to cause a digitally stored sound signal to be modified to correspond to the sound of a note played in the manner indicated by the detected depression of keys. A sound corresponding to the modified signal is then reproduced through a loudspeaker.

The difference in the quality of sound generated by known electronic pianos compared with the quality of

sound generated by a good grand piano, such as a Steinway (Trade Mark) or Bosendorfer (Trade Mark), is very significant. The present invention aims to provide an electronic piano which can generate a quality of sound closer to that of a good acoustic grand piano.

The present invention also aims in a preferred embodiment to provide a digital piano which has much more of the "feel" of a conventional acoustic grand piano than does a conventional electronic piano. In particular, a digital piano of the present invention aims to generate a sound which closely emulates the spatial qualities of a conventional grand piano.

In accordance with one aspect of the present invention there is provided an electronic piano comprising:

a keyboard for generating input signals;

an acoustic signal generator for generating audio signals in response to said input signals;

sound generating means connected to said acoustic signal generator, said sound producing means comprising a panel arranged to generate sound through the inducement of resonant vibrations in said panel; and

support means operable to support said keyboard, said signal generator and said sound producing means in cooperable relationship, wherein said support means is

such as to transmit vibrations generated by said panel to said keyboard.

In accordance with another aspect of the present invention there is provided a kit of parts comprising:

a first housing carrying a keyboard and an audio signal generation system and first sound output means; and

a second housing carrying a second sound output means, said second sound output means being adapted to output sound by the inducement of resonant bending mode vibrations within a panel arranged substantially horizontally within said second housing, wherein said second and first housings when attached adopt the configuration of a grand piano.

In accordance with a further aspect of the present invention there is provided a method of emulating air disturbance patterns characteristic of an acoustic grand piano comprising the steps of:

providing a panel having a plurality of transducers attached thereto;

supporting said panel substantially horizontally within a casing having the configuration of a grand piano; and

inducing bending mode vibrations in said panel utilizing said transducers to generate a sound

corresponding to an audio signal representative of the sound of a grand piano.

Further aspects of the present invention will become apparent from the description and the accompanying drawings, in which:

Figure 1 is a perspective view of a digital piano in accordance with the first embodiment of the present invention;

Figure 2 is an underneath plan view of the piano of Figure 1;

Figure 3 is a cross-section along the line A-A' of Figure 2;

Figure 4 is an illustration of an internal honeycomb structure of a panel;

Figure 5 is a cross-sectional of a transducer attached to a panel;

Figure 6 is a diagram of the piano action and key depression detection system of the digital piano of Figure 1;

Figure 7 is a block diagram of the sound selection system of the digital piano of Figure 1;

Figure 8 is a perspective view of a digital piano in accordance with a second embodiment of the present invention;

Figure 9 is an underneath plan view of a panel for

use in a third embodiment of the present invention; and

Figure 10 is a vertical cross-section of a panel for use in a fourth embodiment of the present invention.

In the digital piano of figure 1 having a sound selection and generation system as is described later, the piano comprises a conventional grand piano such as a Steinway or Bosendorfer in which the harp comprising strings in a supporting framework and soundboard of the piano have been replaced by a panel 1. In this embodiment the panel 1 is arranged to be excited by a plurality of transducers (not shown in Figure 1) in the manner described in WO97/09842, which is hereby incorporated by reference. As in a conventional grand piano, the piano comprises a casing 4 and lid 5 that are supported away from the ground by a plurality of legs 6. Carried on the casing 4 are a conventional grand piano keyboard 7 connected to a mechanical piano action (not shown in figure 1) and a set of three foot pedals 8. The panel 1 is shaped to fit within the casing 4 and extends across the entirety of the area bounded by the casing 4. In this embodiment in which the casing 4 corresponds in size and shape to a baby grand piano, the panel 1 extends for 2020mm away from the keyboard and is shaped having a width of 1235 mm adjacent to the keyboard 7 and narrowing to a width of 590 mm a distance of 340 mm from the edge

adjacent to the keyboard 7 with the periphery of the panel 1 following the shape of the area bounded by the casing 4.

Beneath the keys of the keyboard 7 there is provided an infrared motion detection system for detecting the depression the keys. The foot pedals 8 are connected to switches (not shown in figure 1). The detected combination of the motions of the keys of the keyboard 7 and the depression of the foot pedals 8 is received by a high quality sound selection and generation system (not shown in figure 1) provided within the casing 4 behind the keyboard 7. The sound selection and generation systems then generate an appropriate acoustic sound signal which is reproduced by the panel 1 as is described in detail below.

Figure 2 is a schematic underneath plan view of the piano of Figure 1, and illustrates how the panel 1 is connected to the casing 4. As is shown in Figure 2, the panel 1 is held in place against the casing 4 by a pair of wooden clamps 10,11 at the periphery of the panel 1. The clamps 10,11 each comprise an upper portion situated above the panel 1 (not shown in Figure 2) and a lower portion beneath the panel 1. One of the clamps 10 extends along the entirety of the edge of the panel 1 along the side adjacent to the portion of the edge of the

casing 4 closest to the keyboard. This clamp 10 also extends along part of the long edge of the piano casing 4 with a portion of the panel 1 adjacent to the casing 4 remote from the keyboard 7 being allowed to vibrate freely. The other clamp 11 extends along the curved edge of the grand piano casing 4. A portion of the panel 1 adjacent to the short edge of the grand piano casing 4 is also allowed to vibrate freely.

In this embodiment, the panel 1 is arranged to be compressed by the casing 4 when held in place by the clamps 10,11, with the casing 4 horizontally compressing the panel 1 in the directions indicated by the arrows in Figure 2. By fixing the panel 1 via clamps 10,11 to part of the casing 4 and causing the panel 1 to be horizontally compressed by the casing 4 it is possible to ensure that some of the vibrations created within the panel 1 are transmitted to the casing 4 to give rise to vibrations in the casing 4 in a similar manner to the way in which vibrations from an acoustic soundboard give rise to vibrations in the casing of a conventional acoustic grand piano and hence emulate the feel of a grand piano.

Also shown in Figure 2, arranged on the undersurface of the panel 1 are sixteen transducers 12 such as the 25mm voice coil exciter transducers available from Peerless Fabrikkern A/S which are used to induce

vibrations in the panel 1. The arrangement shown in Figure 2 is merely a schematic representation of the actual arrangement of transducers on the panel 1. Preferably, the arrangement of transducers 12 on the panel 1 is an arrangement in accordance with a determination by a finite element analysis of an optimum arrangement of transducers so that vibrations excited in the panel 1 correspond to vibrations excited in the soundboard of a grand piano over the entire working frequency range of the instrument. When a drive signal is then transmitted to these transducers 12 via wires (not shown) this causes the panel 1 to vibrate in a manner similar to a grand piano soundboard as is described later.

Figure 3 is a vertical cross-section through the panel 1 along the line A-A' in Figure 2. In this embodiment of the present invention the panel 1 comprises a shaped panel 1 having an internal honeycomb structure 20 (which is illustrated in Figure 4) and a pair of outer skins 22,24. In this embodiment, the honeycomb structure 20 comprises paper covered by phenolic resin, and the outer skins 22,24 comprise epoxy resin glass fibre skins.

Since the mass of the honeycomb 20 is much less than that of the skins 22,24 a lightweight panel 1 that is of substantially uniform density across the entirety of the

panel 1 is created. This has the advantage of presenting an isotropic and homogenous acoustic impedance to transverse (bending mode) vibrations conducted through the panel 1. Furthermore, since the panel is of uniform density it is also possible to model the vibrations generated by the transducers 12 accurately to determine the optimum positions for the transducers 12 to achieve uniform output across the frequency range of a grand piano. This can be achieved by identifying the points on the panel corresponding to nodes when the panel is excited to vibrate at different frequencies and locating the transducers at points corresponding to nodes. The energy required to induce vibrations in the panel 1 via the transducers 12 is then minimised by ensuring that the panel 1 is lightweight.

In this embodiment the panel 1 is shaped to vary in thickness from a peripheral thickness of about 5mm to a central thickness of about 15mm. The shaping of the panel 1 is achieved by cutting the internal honeycomb structure 20 to shape by laser cutting or using an ultrasonic knife prior to the attachment of the glass fibre skins 22,24.

As stated previously, in this embodiment the casing 4 and clamps 10,11 are such as to place the panel 1 slightly under horizontal compression to ensure that the

edges of the soundboard communicate vibrations generated to the casing 4. This horizontal compression exerted by the casing 4 is such to cause the panel 1 to adopt a slightly cambered orientation with the undersurface of the board adjacent to the casing 4 being at an angle of between 2 to 5° from the horizontal. In this way the panel 1 is arranged to adopt a shape that is similar to the shape of a conventional acoustic soundboard and therefore when excited by the transducers 12 the panel 1 generates an air disturbance pattern similar to that generated by a conventional acoustic grand piano.

Figure 5 is a detailed cross-section of a transducer 12 connected to a portion of the panel 1. In this embodiment all of the transducers 12 for inducing vibrations in the panel 1 are attached to the underside of the panel 1. Each of the transducers 12 comprises a steel outer casing 26 weighing about 50 grams that it attached to the panel 1 via a plurality of arms 27 that are glued to the panel 1 by cynoacrylate glue. Inside the casing 26 of each transducer 12, is a cylindrical rare earth cobalt iron magnet 28 attached to the casing 26, with the magnet 28 being surrounded by a copper wire coil 29. The arms 29 are arranged to flex allowing limited axial movement of the casing 26 relative to the panel 1 with the coil 29 fixed in position relative to

the surface of the panel 1. When the copper wire coil 29 receives a drive signal this causes the magnet 28 to vibrate flexing the arms 27. The panel 1 moves in an opposite direction to account for the motion of the magnet 28 and casing 26, inducing bending moment vibrations within the panel 1.

Inducing vibrations in the panel 1 using transducers 12 creates our disturbance patterns similar to those created in an acoustic grand piano soundboard. In particular in an acoustic grand piano soundboard the mechanical vibrations of the strings induce vibrations in the soundboard which are at right angles to the surface of the soundboard. This causes pressure waves to radiate from the surface of the soundboard which are reflected by and induce vibrations in the casing surrounding the soundboard. The interaction of the soundboard and casing is such as to give rise to soundwaves which predominantly travel upwardly and downwardly which are then reflected by the lid 5 and ground respectively. The soundwaves also induce vibrations in the casing which is perpendicular to the soundboard. Together, these combine to cause the generation of air disturbance patterns characteristic of a grand piano. In the present embodiment a comparable effect is achieved by inducing bending mode vibrations in a panel 1 which vibrates

primarily upwardly and downwardly but also which vibrates in the plane of the panel 1. Soundwaves generated in the surrounding air by the vibrating panel 1 then travel upwardly and downwardly in a similar manner to those generated by a conventional acoustic soundboard, with the soundwaves being reflected by the lid 5 and ground whilst vibrations in the plane of the panel 1 are at the same time transmitted to the casing 4 as the panel 1 is in pressure contact with the casing. By providing a casing 4 shaped to correspond to the shape of a conventional piano casing these combine to generate an air disturbance pattern comparable to that generated by an acoustic grand piano.

By providing the panel 1 in the position where the harp and soundboard of a conventional acoustic grand piano would be it is possible to emulate more closely the spacial aspects of sound generated by an acoustic piano. In particular, this can be achieved by having a plurality of transducers 12 generate sound from the entirety of the surface of a panel 1 rather than providing a sound source comprising a number of point sources. This combined with the generation of soundwaves both upwardly and downwardly generates an acoustic directivity pattern which is similar to the acoustic directivity pattern of sounds generated by striking the strings of a conventional

acoustic grand piano.

With reference to Figure 6, each of the keys 101 of the keyboard 7 is connected via an action mechanism 102 to a hammer 103. This embodiment of the invention preferably utilises a high quality conventional grand piano action mechanism for transmitting the movement of the keys to the hammers each time a key is depressed in order to provide for the player a feel which closely resembles the feel of a good quality grand piano. Ideally, therefore, the action used is the same as that used in a conventional grand piano such as the Steinway or Bosendorfer. The hammer 103 and action mechanism 102 are arranged so that when a musician strikes a key 101 the hammer is caused to strike a sound absorbing material such as a rubber strip 104. An infrared pickup 105 such as one of the pick ups of the Gabor system (Trade Mark) touch sensitive pick-up switch strips manufactured by GB Musical Enterprises Limited, is arranged beneath each of the keys of the keyboard 7 to detect each time a key is depressed.

By providing a keyboard 7 having an action 102 that causes hammers to be moved, the digital piano of this embodiment has a feel similar to a conventional piano. The detection of movement by the infrared pick-up 105 does not influence how the keyboard feels to the player

since the infrared pickup 105 can detect the motion of the keys without mechanical interference with the motion of the action 102. The hammers 103 are arranged to strike a sound absorbing strip 104 so that the sound generated by the motion of the hammer 103 is minimised and hence does not detract from the sound generated by the panel 1.

Figure 7 is a block diagram of the sound selection system of digital piano of Figure 1. The sound selection system comprises a computer 106 which is connected to the infrared pickups 105 beneath the keys of the keyboard. The computer 106 is also connected via foot pedal switches 107 to the foot pedals 5 of the digital piano.

When a musician depresses the keys of the keyboard 7 the motion of the keys is detected by the infrared pickups 105 which generate a MIDI (Musical Instrument Digital Interface) signal which is sent to the computer 106. If the foot pedals 8 are depressed this causes the foot pedal switches 107 to be activated to send a signal to the computer 106 to indicate which of the damper, soft and sustain pedals is being depressed. Together, the signals received from the infrared pickups 105 and the foot pedal switches 107 provide an indication of how the piano is being played.

When a signal is received from the infrared pickups

105 and the foot pedal switches 107, the computer 106 is caused to select a sound sample corresponding to the MIDI signal received, adjusted to account for the effect of the foot pedals. A suitable computer 106 could comprise a Giga Sampler (TM) which is arranged to select instrument samples read directly from a high speed hard disc such as an IBM Ultrastar SCSI U2W9.1 Gigabyte hard drive or other mass storage device. When an appropriate sample has been selected, a sound card such as a Yamaha SW1000xGPCI Sound Card within the computer 106 generates an audio signal corresponding to the selected sample. By providing a large library of sound samples of different notes played on a conventional grand piano such as a Steinway, Bosendorfer or Yamaha, audio signals that accurately model the sound of a conventional piano can be generated for the entire range of sounds of a conventional piano.

Connected to the sound card of the computer 106 is an amplifier 108. In this embodiment the amplifier 108 comprises 700 watt single channel amplifier which amplifies the audio signal output by the computer 106. This amplified signal is then transmitted to the coils 29 of the transducers 12 attached to the panel 1 which cause the transducers 12 to generate bending mode vibrations in the panel 1 so that the vibrational energy from the

transducers 12 radiates across the full extent of the panel 1, thereby causing air disturbance patterns similar to those generated by an acoustic instrument.

The applicant has appreciated that in order for a digital piano to more closely emulate the perceived spatial variations in sound which arise in an acoustic grand piano and hence more closely emulate the sound and feel of a conventional grand piano, it is necessary to replicate air disturbance patterns similar to those generated by an acoustic instrument.

The applicant has appreciated that the perceived spatial variations in the sound arise in part due to the direction in which sound waves travel. In a conventional grand piano the sound waves generated by the vibration of strings are of greatest magnitude in a direction perpendicular to the plane in which the strings lie. For a grand piano with a horizontal frame, the strings extend horizontally. In the preferred embodiments, a sound source is arranged in the plane where the harp of such a conventional grand piano would normally be found. In this way an electronic sound source is provided which mimics the action of the soundboard of a convention acoustic grand piano. It is therefore possible to emulate the apparent directional variation of the sound of a piano as well as the apparent source of the sounds

generated and thereby improve the ability of a digital piano to emulate a conventional piano.

It has also been appreciated that the perceived spatial variation of a conventional piano arises from the fact that a conventional acoustic piano sound board generates sound across the entirety of its surface. Thus the sound source of the present invention is selected so as to be an area sound source rather than point sound source such as a conventional loudspeaker generating vibrations in air via a pistonic action.

Furthermore, by providing a casing 4, lid 5 and legs 6 made from conventional materials and arranged in a conventional manner, the effect of the interaction of the sound waves with the casing 4, lid 5 and legs 6 should also be similar to the interactions which occur in a conventional grand piano and hence further enhance the emulation of the sound of a conventional grand piano. The fixing of the panel to the casing 4 in a similar manner to the fixing of a conventional soundboard to the casing of a conventional piano also acts to ensure that these other parts of the piano vibrate in a conventional manner. In particular the shaping of the panel 1 and the placing of the panel 1 under horizontal compression by the casing cause vibrations in the casing 4, lid 5 and keys 6 similar to those in a conventional piano. This in

addition to the vibrations caused by the panel 1 being conveyed to a musician directly through the piano and via the floor in a manner similar to an acoustic piano, acts to improve the emulation of the feel of an acoustic grand piano.

A piano in accordance with this embodiment of the present invention, could be purpose built or alternatively a conventional acoustic grand piano, could be converted into a piano in accordance with this embodiment. If an acoustic piano is to be converted into a piano in accordance with this embodiment, the conversion would be performed by removing the harp and sound board of the conventional piano replacing them with a panel as has previously been described and installing equipment for detecting the depression of keys and foot pedals of the conventional piano together with a sound generation system as has also been described for generating a drive signal utilizing detected key and pedal depressions.

Figure 8 is a perspective view of a piano in accordance with a second embodiment of the present invention. In the previous embodiment a digital piano was provided in which a panel 1 was held within a unitary casing 4 in which also carried a keyboard 7 and foot pedals 8. In this embodiment of the present invention a

piano is provided which is divided into two parts. A first portion 200 is provided which is arranged to carry a keyboard 201, a set of foot pedals 202, a sound generation system (not shown in Figure 8) and a conventional sound output system using loudspeakers. In accordance with this embodiment of the present invention this first portion 200 of the piano could be used in the manner of a conventional digital piano. Also provided in accordance with this embodiment of the present invention is a second portion 210 comprising a casing 212, a lid 214 and a panel 216 arranged to be excited via transducers (not shown in Figure 8) in the manner described in relation to the first embodiment. The second portion 210 in this embodiment is shaped so that when it is attached to the first portion 200 of the piano, the combined instrument has the physical appearance of a conventional grand piano. In this embodiment the casing 212 comprises a number of separable portions allowing the casing 212 to be dismantled and flat packed.

Thus in accordance with this embodiment of the present invention the first portion of the piano 200 may be used in the manner of a conventional digital piano in the absence of the second portion 210. If, however, a sound more closely emulating a grand piano sound is

required the second portion 210 of the piano can be connected to the first portion with the sound generated by the sound system of the first portion 200 being played through the panel 216 of the second section 210 with the conventional sound output system being disabled. The instrument formed by combining the first 200 and second portions 210 of a piano in accordance with this embodiment will then give rise to air disturbance patterns comparable to those generated by a grand piano since the location of the origin of the sound from the instrument and its physical shape will be comparable to that of a conventional instrument. Thus connecting the two portions of the instrument enables the piano of the first portion 200 to more closely emulate a grand piano when desired for example when performing a concert. Providing a casing 212 that is formed from a number of separable portions enables the second portion 210 to be dismantled and stored. When reassembled for use, the assembly of the second portion 210 requires fixing of the panel 216 to the casing 212 in a manner which clamp, the panel 216 under horizontal compression using horizontal clamping forces applied by screw couplings (not shown).

Figure 9 is a schematic underneath plan view of a panel 300 with a plurality of transducers 301-306 attached for use in a third embodiment of the present

invention. In the previous embodiments a panel has been described having attached thereto a plurality of transducers arranged in a manner which optimises frequency response from the entirety of the panel.

In this embodiment a plurality of transducers 301-306 are attached to the panel 300 along a line which on a conventional acoustic piano soundboard would be occupied by the bridge. In this embodiment of the present invention in contrast to the previous two embodiments the sound generation system is arranged to send to the transducers 301-306 signals corresponding to different ranges of frequencies of notes of the output generated by the computer. In particular in this embodiment the transducers 301,302 are arranged to receive signals corresponding to low frequency notes, the transducers 303 and 304 are arranged to receive signals corresponding to notes having frequencies in the middle of a piano's range and, transducers 305 and 306 are arranged to receive signals corresponding to notes with frequencies at the higher end of the range of frequencies of sounds generated by a conventional piano. The selection of signals sent to each of the transducers 301-306, could either be determined by dividing a drive signal into a number of different drive signals corresponding to different frequency ranges using an

active crossover network or alternatively the MIDI signals generated by a keyboard sensing system indicating which keys are being played could be used to select which transducers receive drive signals.

In this way by sending different signals to the different groups of transducers it is possible to cause high frequency sounds to be created and predominantly emanate from the portion of the panel 300 which would correspond to the portion of a soundboard beneath the higher pitched strings in a conventional piano, medium frequency sounds to emanate predominantly from a portion of the panel 300 corresponding in position to the portion of a conventional soundboard excited by vibrations of medium pitch strings and low frequency sounds to predominantly emanate from the portion of the panel 300 corresponding to the portion of a conventional soundboard which would normally be excited by vibrations of lower pitch strings. Thus by arranging the transducers in this manner and sending different signals to different transducers the generation of sound by the panel 300 more closely emulates the generation of sound from a conventional acoustic piano as the spatial distribution of the origin of sounds at different frequencies more closely corresponds to the spatial distribution of the origin of sounds of those frequencies from a conventional

piano soundboard.

Figure 10 is a vertical cross-section of a portion of a panel for generating sound in accordance with a fourth embodiment of the present invention. The panel of Figure 10 is intended for use in a piano as has been described in relation to the first or second embodiments, description of which will not be repeated here. In this embodiment the panel comprises a honeycomb structure 350 having attached to its upper and lower surfaces skins 351, 352 in a similar manner to the panel 1 of the first embodiment. However, in contrast to the sound boards of the previous embodiments, in this embodiment instead of a transducer being attached to one of the skins 351,352 of the panel, in this embodiment transducers 353 are provided within the honeycomb structure. Wires 354 connecting the transducer 353 to the sound generation system of a digital piano are also contained within the honeycomb structure 350 of the panel. By providing transducers within the honeycomb structure 350 of the panel means is provided to protect the wiring 354 and the transducer 350 through interference or damage.

Actuation of the transducer 353 causes vibration of the transducer 353 which is coupled to the skins 351 and 352 via the honeycomb or via mountings connecting the transduces 353 to the skins 351,352. The skins 351,352

are thereby induced to vibrate in 1 bending mode such that the vibrational energy from the transducer 353 is distributed across the panel as in previous embodiments.

Although in previous embodiments panels have been described comprising a shaped honeycomb structure to which fibreglass skins are attached other forms of panel could be used. Instead of a honeycomb structure a panel comprising a lightweight foam core could be used as could any other lightweight support structure which enables a pair of skins to be separated from each other creating a stiff rigid panel. A panel could be shaped in the manner previously described or alternatively a flat panel could be used.

Although in previous embodiments a panel has been described which is clamped at its periphery to a casing and placed in horizontal compression, a panel for outputting sound by resonant vibrations could be held in position by other means. For example, a number of supports could be provided to support a panel from underneath without the periphery of the panel being clamped or the panel being placed under horizontal compression. If a panel is to be supported from below, preferably the supports are arranged to support the panel at points on its surface corresponding to antinodes when the panel is excited to vibrate at frequencies

corresponding to frequencies of notes of a grand piano to minimise the influence of such supports from preventing the surface of the panel from vibrating.

Although in previous embodiments a motion detection system for detecting the motion of keys has been described utilizing infrared motion detection, other means may be used to detect the depression keys for example an electromechanical motion detection system could be used to detect the position, pressure and velocity of key activation.

In Figure 7, the infrared pick-ups 105 are used to generate a MIDI signal which is separate from the output of the foot pedals 6. Alternatively, the foot pedals 6 and infrared pick ups 105 may be connected to the computer 100 via the same interface so that the MIDI signal includes the foot pedal control signals.

Although in the previous embodiments a sound generation system has been described in which sound samples are selected from a number of sound samples stored within a hard disc, sound samples for an electronic piano in accordance with the present invention could be generated in other ways. For example a recorded sample could be modified to generate different notes of different pitch rather than having individual notes stored separately on a hard disc. The recording of sound

samples may either be based on a conventional recording of the sound of a grand piano or alternatively individual drive signals could be selected where the drive signals are recorded utilizing recordings of sound generated at a point on the sound board corresponding to the position of a transducer which is to be driven by a recorded drive signal.

Although in previous embodiments pianos have been described which output sound via a panel by electromagnetic transducers arranged underneath or within a panel other arrangement of traducers could be used, for example transducers could be arranged on the upper surface of a panel or alternatively a combination of positions of transducers on the upper and lower surfaces of a panel or within a panel could be used.

Although in the previous embodiments pianos have been described which generate sound on the basis of detected key actuations, pianos of the present invention could generate sound on the basis of prerecorded MIDI files in order to recreate a recorded performance in a manner a Peanola. Alternatively a piano in accordance with the present invention could have means for recording a performance detected and converted into a MIDI file for later playback.

Although in the previous embodiments pianos have

been described which output sound via a panel excited by electromagnetic transducers, other forms of distributed mode acoustic resonators could be used. For example a panel having multiple piezoelectric transducers on its surface could be used. In such a case a processor could be required to process the output audio sound signals to create a multiple drive signals which excite respective piezoelectric drivers in a pseudo random manner to entrance the distributed mode of vibration. Another alternative means for providing sound which emanates from an area rather than from a point source would be to provide a Quad electrostatic loudspeaker arranged to be excited electrostatically across the surface of its sound producing diaphragm.

Although in previous embodiments a single sound source has been provided which is arranged to generate sound across the entirety of the area ordinarily occupied within a conventional grand piano by the sound board and harp, two or more panels could be provided for generating sound. The planar extent of the base of the soundbox could therefore be divided into a number of separate regions occupied by respective panels. The panels could be separately energised according to the musical notes being played to achieve enhanced spatial realism similar to the effect described with reference to Figure 9.

Furthermore, panels for generating sound could form part of the casing or lid of a piano. Alternatively portions of the casing could be directly excited by transducers causing resonant vibrations. In this way the casing and lid or portions of the casing and lid could directly act as the sound board for the digital piano and there being no need to provide separate panel which is carried within the casing. In such an embodiment it would be necessary for the casing and lid or portions of the casing and lid to be made of a material which can both be excited by transducers to cause resonant vibrations and which has sufficient strength to enable the casing on the lid to perform the standard functions of a casing and lid of a conventional acoustic grand piano.

Each of the above embodiments may additionally include an effects processor as an adjunct to the amplifier 108 and an inducing the facility to vary volume, equalisation and revelation control applied to the acoustic signals in order to emulate the environment in which the grant piano is to be emulated. For example, different reverberation settings can be used to simulate halls of different sizes.

Additional functionality of the instrument may be provided by other effects such as chorus, to obtain

sounds not available from a conventional grand piano.

Other effects could also be created by modifying the sound of recorded samples. Also, alternative sound sources other than a grand piano could be recorded and used to generate for example the sound of a harpsichord, Fender Rhodes piano or a vibraphone.

Alternatively synthesised sounds could be used as the basis for generating drive signals for a panel in accordance with the present invention.

Furthermore in accordance with the present invention the amplifier 106 and panel 1 could be used to output sounds other than those generated in response to actuation of the keyboard. For example, the orchestral score for backing a piano piece could be played from either a midi file or CD and output through a panel whilst piano sounds played on the basis of detected depression of keys and pedals are output.

CLAIMS:

1. An electronic instrument comprising:

a keyboard comprising keys corresponding to musical notes;

an acoustic signal generator connected to the keyboard and responsive to actuation of the keyboard to generate corresponding audio signals;

sound producing means connected to the signal generator and responsive to the audio signals to produce sounds corresponding to the musical notes, said sound producing means comprising a substantially planar soundboard and transducer means responsive to the audio signals to induce resonant vibrations in the soundboard; and

support means operable to support the keyboard, signal generator and the sound producing means in a cooperable relationship, said support means comprising fixing means for fixing at least part of the periphery of said soundboard to the support means, said fixing means being such as to transmit vibration in said soundboard to said support means.

2. An electronic instrument as claimed in claim 1 wherein the soundboard of said sound producing means is arranged to extend in use substantially horizontally away

from the keyboard.

3. An electronic instrument as claimed in any preceding claim, wherein said sound producing means comprises a soundbox wherein said soundboard forms a bottom surface of said box.

4. An electronic instrument as claimed in any preceding claim wherein said soundbox is in the shape of a grand piano casing.

5. An electronic instrument as claimed in any preceding claim wherein the transducer means comprises a plurality of transducers at locations which are distributed with respect to the planar extent of the sound board.

6. An electronic instrument as claimed in claim 4 wherein said signal generator is operable to selectively excite the transducers according to the frequency content of the drive signal.

7. An electronic instrument as claimed in claim 5 wherein said signal generator is arranged to excite transducers selectively, the signals used to excite transducers being selected so as to correspond to the

frequencies of strings which would vibrate in a comparable portion of a conventional grand piano soundboard to where a transducer is located on said soundboard.

8. An electronic instrument as claimed in any preceding claim wherein the sound board comprises upper and lower surfaces and wherein the upper surface is convex.

9. An electronic instrument as claimed in claim 8 wherein the lower surface is concave.

10. An electronic instrument as claimed in any preceding claim wherein the sound board is held in compression along two mutually horizontal orthogonal axes.

11. An electronic instrument as claimed in any preceding claim wherein the sound board is of composite construction, comprising upper and lower membranes spaced apart by a cellular walled spacing member.

12. An electronic instrument as claimed in claim 11 wherein the transducers are attached to the lower membrane.

13. An electronic instrument for emulating a grand piano; comprising:

a sound box having a shape corresponding substantially to that of a grand piano;

a panel forming a bottom surface of the sound box and extending substantially horizontally in use;

a keyboard;

a supporting structure supporting the keyboard and soundbox in the configuration of a grand piano;

transducer means for exciting bending mode vibrations in the panel;

a signal generator for generating drive signals to excite the transducer means in response to actuation of the keyboard; and

compression means for maintaining the sound board under longitudinal compression along at least one horizontal axis.

14. An electronic instrument as claimed in any preceding claim wherein the panel comprises upper and lower surfaces and wherein the upper surface is convex.

15. An electronic instrument as claimed in claim 14 wherein the lower surface is concave.

16. An electronic instrument as claimed in any of claims 13 to 15 wherein the panel is held in compression along two mutually horizontal orthogonal axes.

17. An electronic instrument as claimed in any of claims 13 to 16 wherein the panel is of composite construction, comprising upper and lower membranes spaced apart by a cellular walled spacing member.

18. An electronic instrument as claimed in any of claims 13 to 17 wherein the transducer means comprises a plurality of transducers at locations which are distributed with respect to the planar extent of the panel.

19. An electronic instrument as claimed in claim 17 wherein said transducer means comprise a plurality of transducers at locations which are distributed with respect to the planar extent of the panel and the transducers are attached to the lower membrane.

20. An electronic instrument as claimed in any of claims 18 or 19 wherein the signal generator is operable to selectively excite the transducers according to the frequency content of the drive signal.

21. A method of constructing an electronic instrument emulating a grand piano, the method comprising the steps of:

removing the strings and existing sound board from a strung grand piano;

replacing the existing sound board with a sound board comprising an electrically excitable distributed mode acoustic radiator;

installing a keyboard sensing system for sensing actuation of a keyboard of the grand piano;

installing a signal generator having an input connected to the keyboard sensing system and an output connected to drive the acoustic radiator.

22. A kit of parts comprising:

a keyboard operable to generate input signals representative of musical notes;

an acoustic signal generator connected to the keyboard responsive to the input of signals to generate audio signals;

a first sound output means responsive to said audio signals; and

a first housing operable to support said keyboard said acoustic signal generator and said first sound output means; and

a second housing releasably attachable to said first housing for supporting a second sound producing means arranged to be connected to the acoustic signal generator responsive to the audio signals to produce sounds corresponding to the musical notes, wherein when attached said first and second housings have a configuration of a grand piano.

23. A kit in accordance with claim 22 wherein said second sound producing means comprises means for generating sound by including resonant vibrations the substantially planar structure.

24. A kit in accordance with claim 22 wherein said second sound producing means comprises a soundboard; and

transducer means for exciting resonant mode vibrations in the soundboard.

25. A kit in accordance with any of claims 22 to 24, wherein said second detachable housing comprises a plurality of separable parts.

26. A kit in accordance with claim 25, wherein said separable parts are adapted to adopt a first configuration when assembled whereby when said second

detachable housing is attached to said first housing said first and second housing have a configuration of a grand piano and a second configuration when disassembled which occupies a smaller volume than said first configuration.

27. An electronic instrument for emulating a grand piano comprising:

a sound box having a shape corresponding substantially to that of a grand piano;

a panel forming a bottom surface of the sound box and extending substantially horizontally in use;

a keyboard;

a supporting structure supporting the keyboard and soundbox in the configuration of a grand piano;

transducer means for exciting bending mode vibrations in the panel; and

a signal generator for generating drive signals to excite the transducer means in response to the actuation of the keyboard, wherein the transducer means is located such that, when viewed in vertical projection the positions at which the panel is excited correspond substantially to positions at which a bridge of a grand piano contacts a soundboard of a grand piano.

28. An electronic instrument as claimed in claim 27

wherein the transducer means comprises a plurality of transducers at locations which are distributed with respect to the planar extent of the sound board.

29. An electronic instrument as claimed in claim 27 wherein said signal generator is operable to selectively excite the transducers according to the frequency content of the drive signal.

30. An electronic instrument as claimed in claim 27 wherein said signal generator is arranged to excite transducers selectively, the signals used to excite transducers being selected so as to correspond to the frequencies of strings which would vibrate in a comparable portion of a conventional grand piano soundboard to where a transducer is located on said soundboard.

31. An electronic instrument as claimed in of claims 27 to 30 wherein the sound board comprises upper and lower surfaces and wherein the upper surface is convex.

32. An electronic instrument as claimed in claim 31 wherein the lower surface is concave.

33. An electronic instrument as claimed in any of claims 27 to 32 wherein the sound board is held in compression along two mutually horizontal orthogonal axes.

34. An electronic instrument as claimed in any of claims 27 to 33 wherein the sound board is of composite construction, comprising upper and lower membranes spaced apart by a cellular walled spacing member.

35. An electronic instrument as claimed in claim 34 wherein the transducers are attached to the lower membrane.

36. A method of emulating air disturbance patterns generated by an acoustic grand piano comprising:

providing a substantially planar soundboard mounted within a support means shaped substantially to correspond to the appearance of a grand piano casing;

providing transducer means arranged on receipt of an audio signal to induce resonant bending mode vibrations in said soundboard;

generating audio signals corresponding to the sound of a grand piano; and

outputting audio sound corresponding to said audio signals by inducing resonant bending moment vibrations in

said soundboard utilizing said transducers.

37. A method in accordance with claim 36, further comprising the steps of providing a keyboard comprising keys corresponding to musical notes;

wherein said step of generating audio signals comprises generating audio signals in response to the actuation of said keys on said keyboard.

38. A method in accordance with claim 36 or claim 37, further comprising the step of fixing at least part of the periphery of said soundboard to said support means so as to transmit vibration of said soundboard to said support means.

39. A method in accordance with claim 38, wherein said fixing step comprises clamping a portion of the periphery of said soundboard so that at least part of said periphery of said soundboard is free to vibrate.

40. A method in accordance with any of claims 36 to 39, wherein said soundboard is arranged to extend substantially horizontally within said support means.

41. A method in accordance with any of claims 36 to 40,

wherein said transducer means comprise a plurality of transducers;

wherein said output step comprises the steps of generating a plurality of drive signals on the basis of the frequency content of said audio signals and exciting said transducers utilizing said drive signals.

42. A method in accordance with claim 41, wherein said transducers are arranged to excite different portions of said soundboard, wherein the drive signal utilized to excite the transducer is selected so as to correspond to the frequencies of strings which would vibrate in a comparable portion of a grand piano soundboard to where a transducer is located on said soundboard.

43. A method in accordance with any of claims 36 to 42, wherein said substantially planar soundboard comprises upper and lower surfaces wherein said upper surface is convex.

44. A method in accordance claim 43, wherein the lower surface is concave.

45. A method in accordance with any of claims 36 to 44, further comprising the step of holding said soundboard in

compression along two horizontal mutually orthogonal axes within said support means.

46. A method in accordance with any of claims 36 to 45, wherein said soundboard is of composite construction, comprising upper and lower membranes spaced apart by a cellular wall spacing member.

47. A method in accordance with any of claims 36 to 46, wherein said support means comprises a first detachable housing for supporting said substantially planar soundboard and a second detachable housing for supporting a keyboard, further comprising releasably attaching said first and second housings thereby providing a support means shaped substantially to correspond to the appearance of a grand piano.

48. A method of emulating air disturbance patterns generated by acoustic grand piano comprising:

providing a keyboard operable to generate input signals representative of musical notes and an acoustic signal generator connected to said keyboard responsive to the input of signals to generate audio signals, said keyboard and said acoustic signal generator being mounted within a first housing;

providing a substantially planar soundboard mounted within a second housing and transducer means arranged to induce resonant bending moment vibrations in said soundboard;

releasably connecting said second housing to said first housing, said first housing and second housing thereby adopting a configuration substantially corresponding to the appearance of a grand piano casing;

generating input signals representative of musical notes;

generating audio signals corresponding to the sound of a grand piano on the basis of input signals; and

outputting an audio sound corresponding to said audio signals by inducing measurement bending moment vibrations in said soundboard utilizing said transducers.

FIG. 1

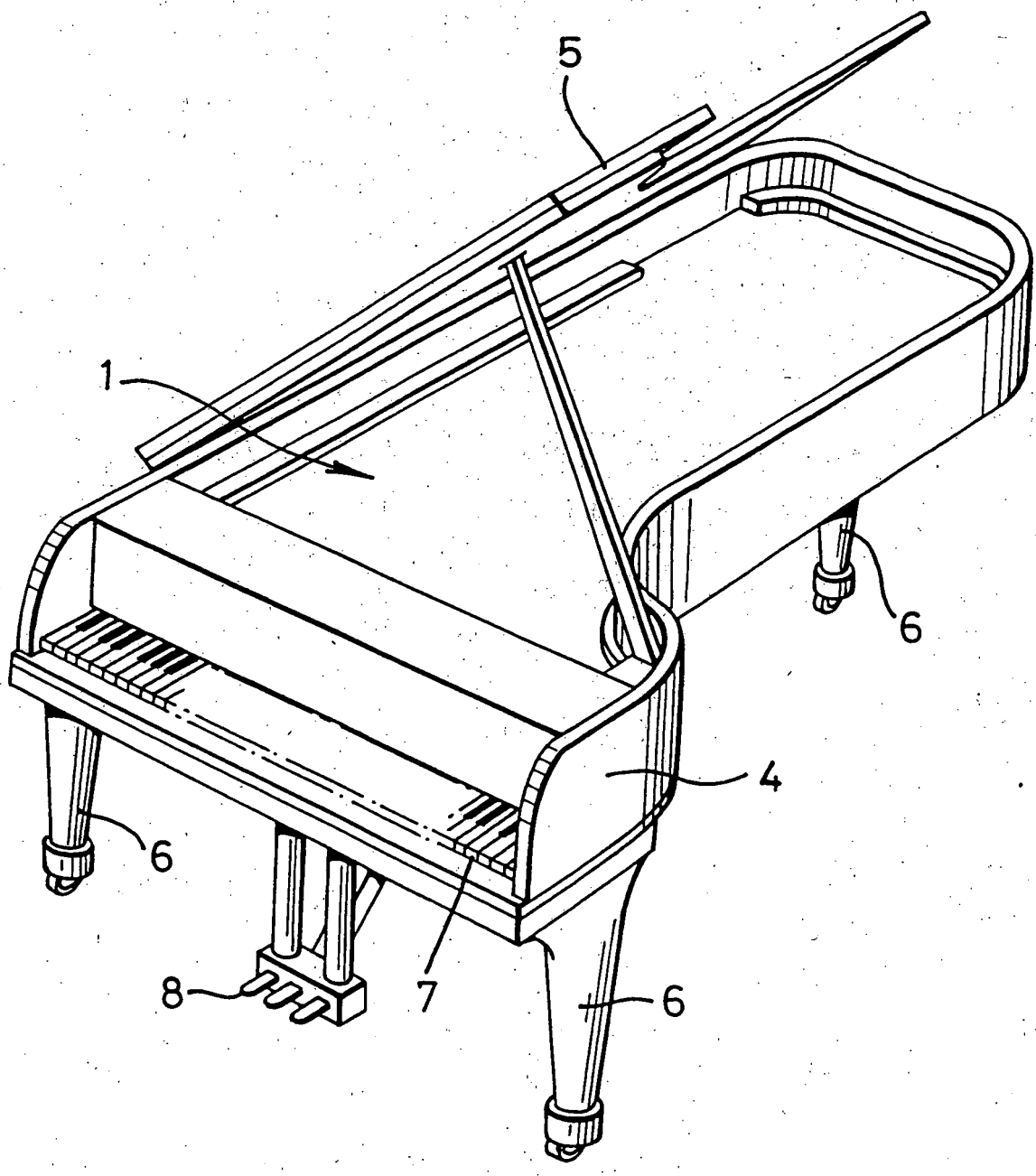


FIG. 2

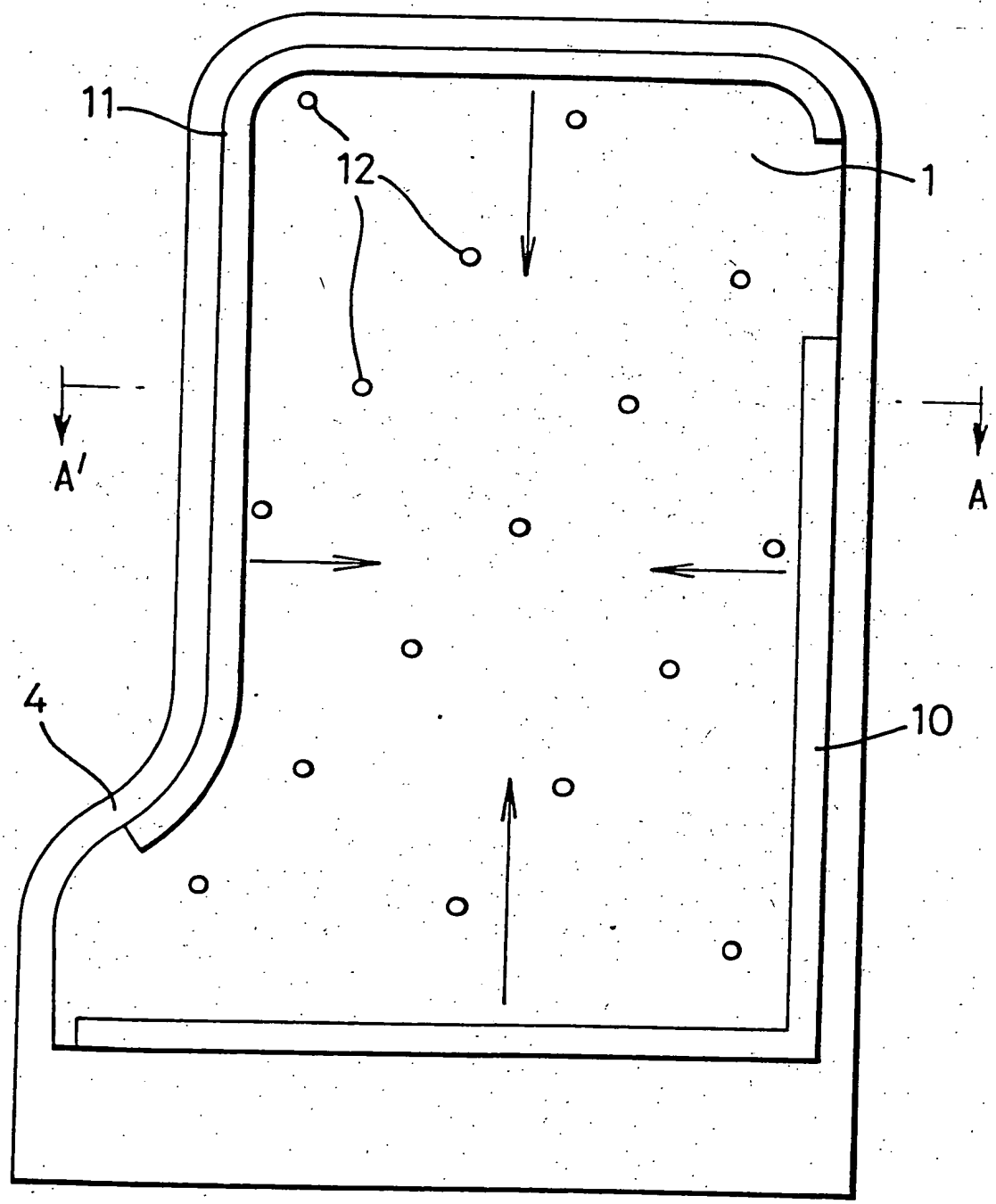


FIG. 3

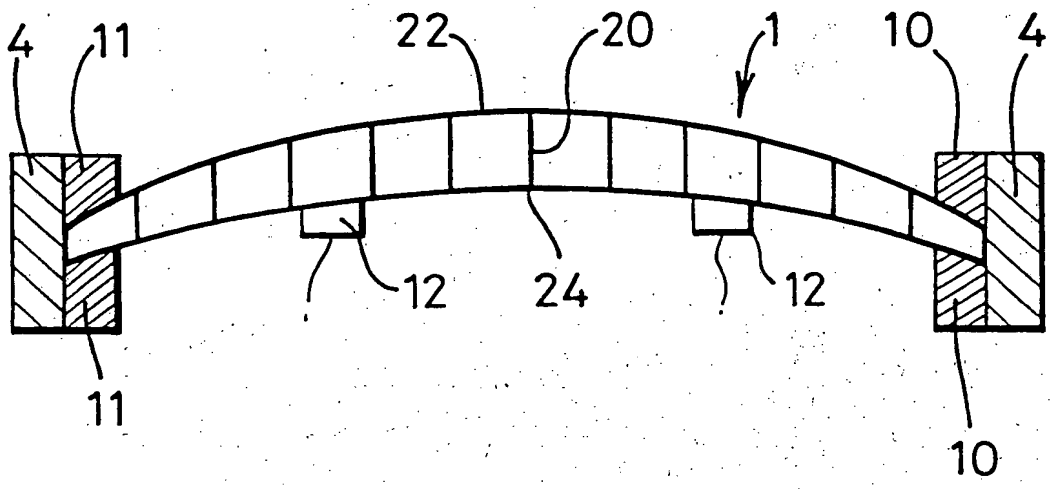


FIG. 4

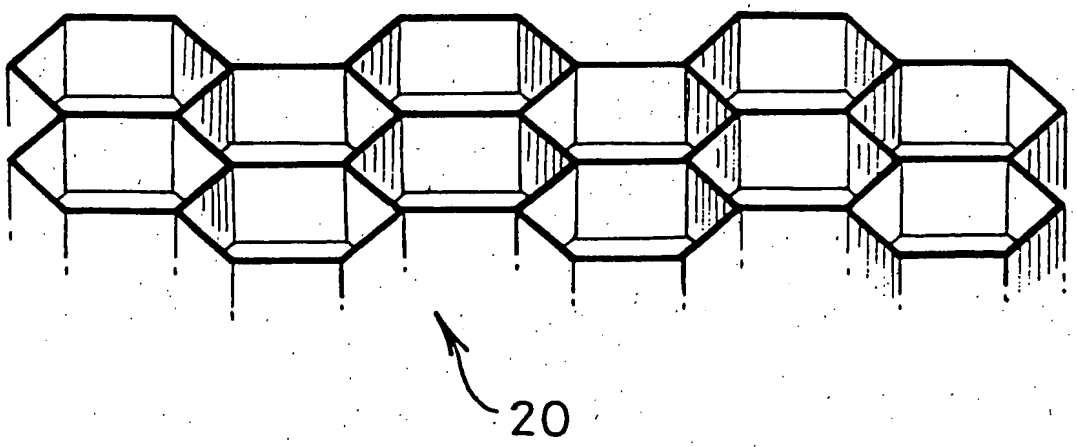


FIG. 5

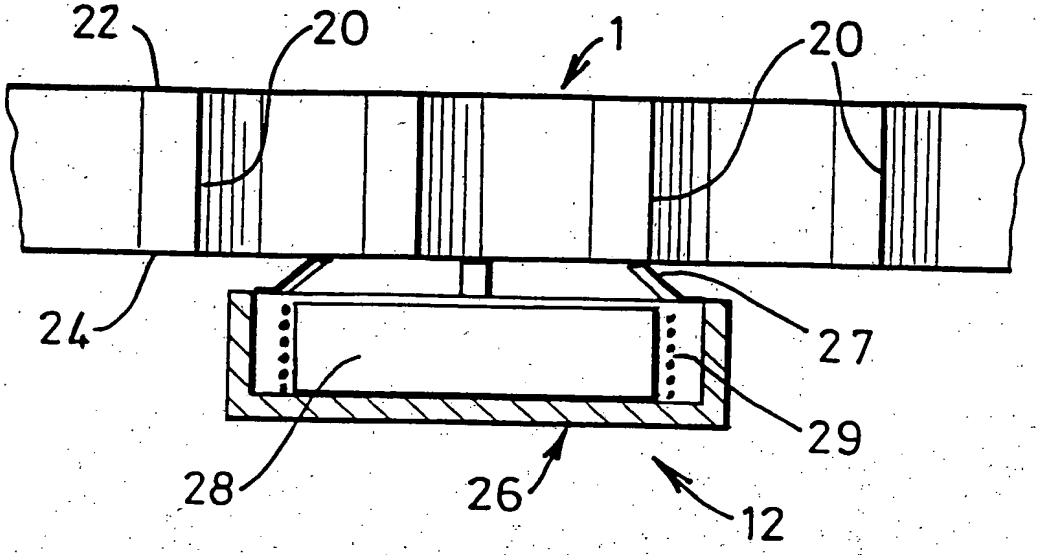
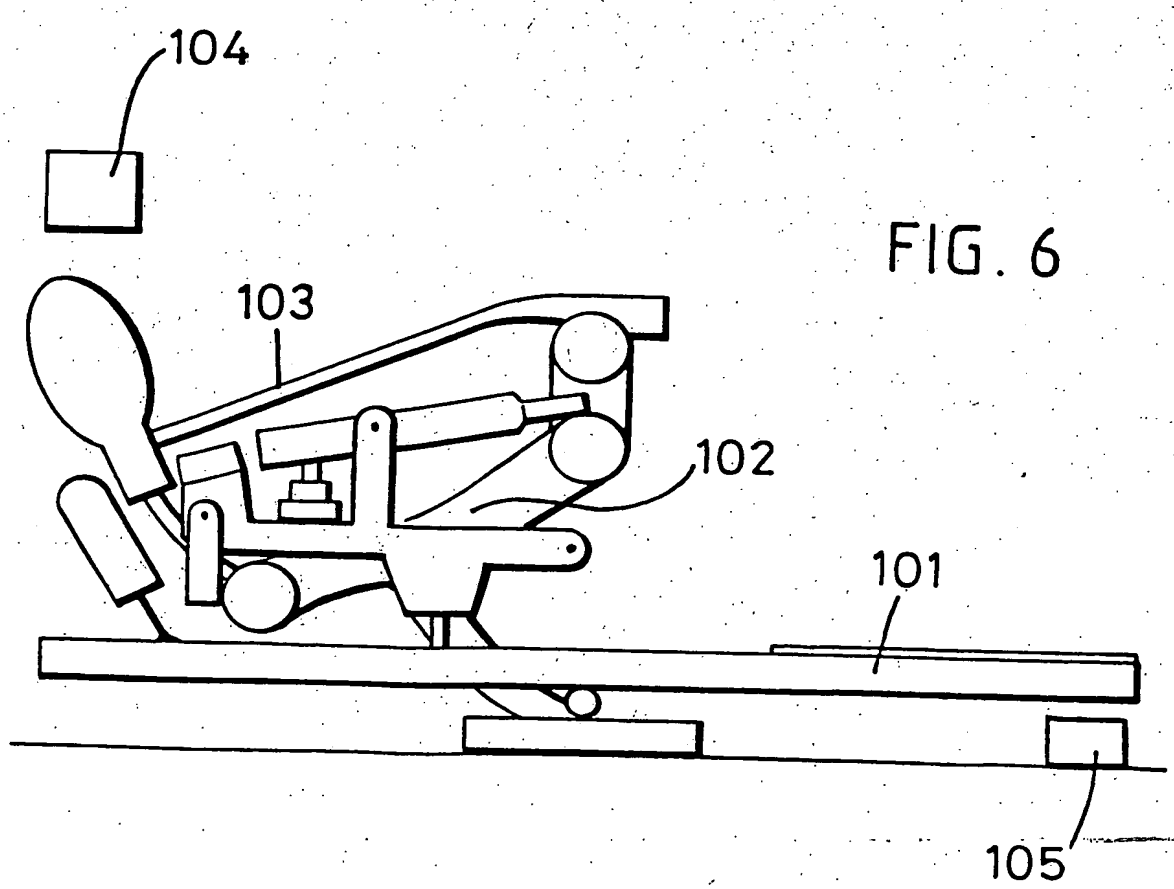


FIG. 6



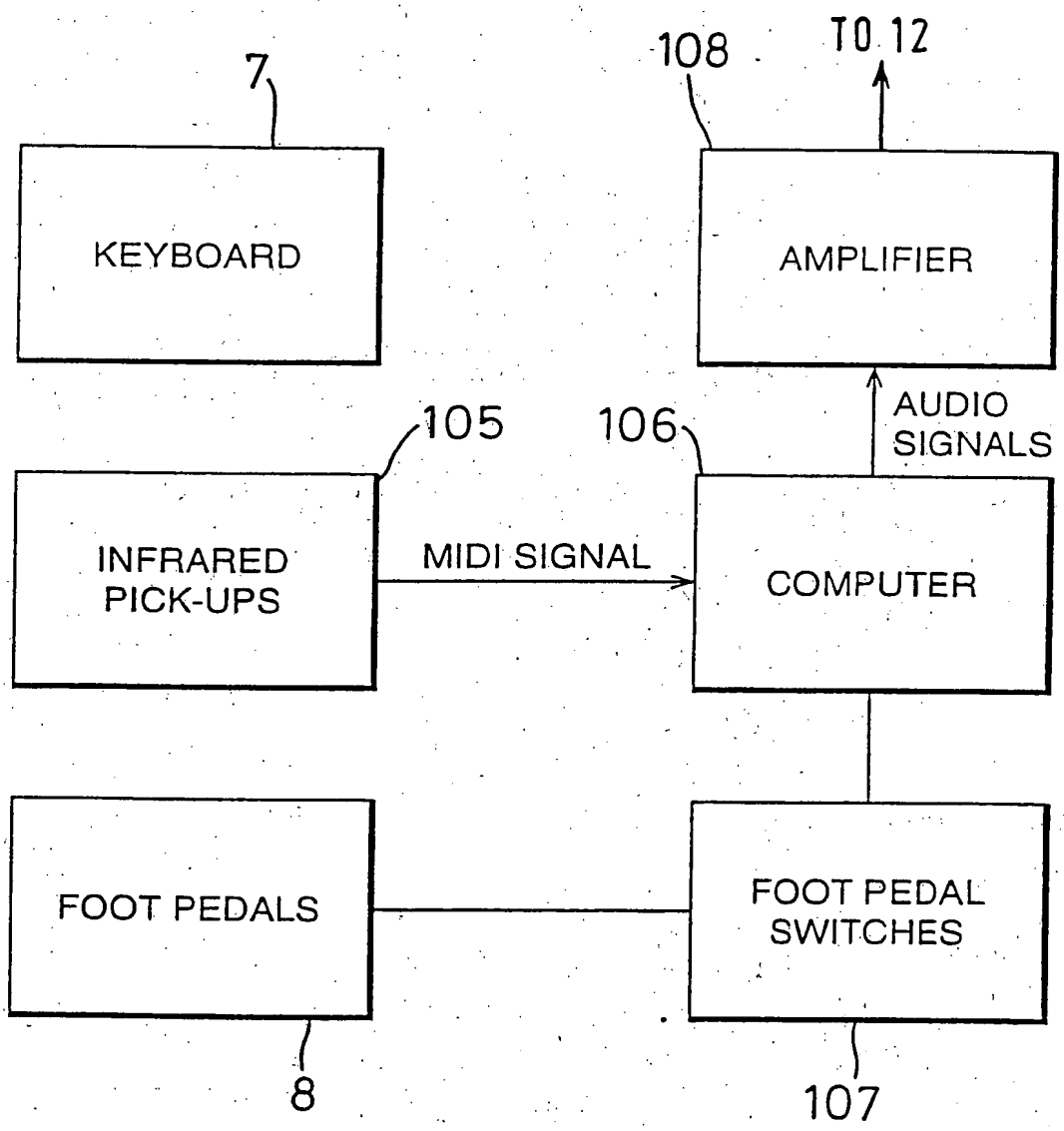

7
KEYBOARD
108
TO 12
AMPLIFIER
AUDIO SIGNALS
105
106
INFRARED PICK-UPS
MIDI SIGNAL
COMPUTER
FOOT PEDALS
FOOT PEDAL SWITCHES
8
107

FIG. 7

FIG. 8

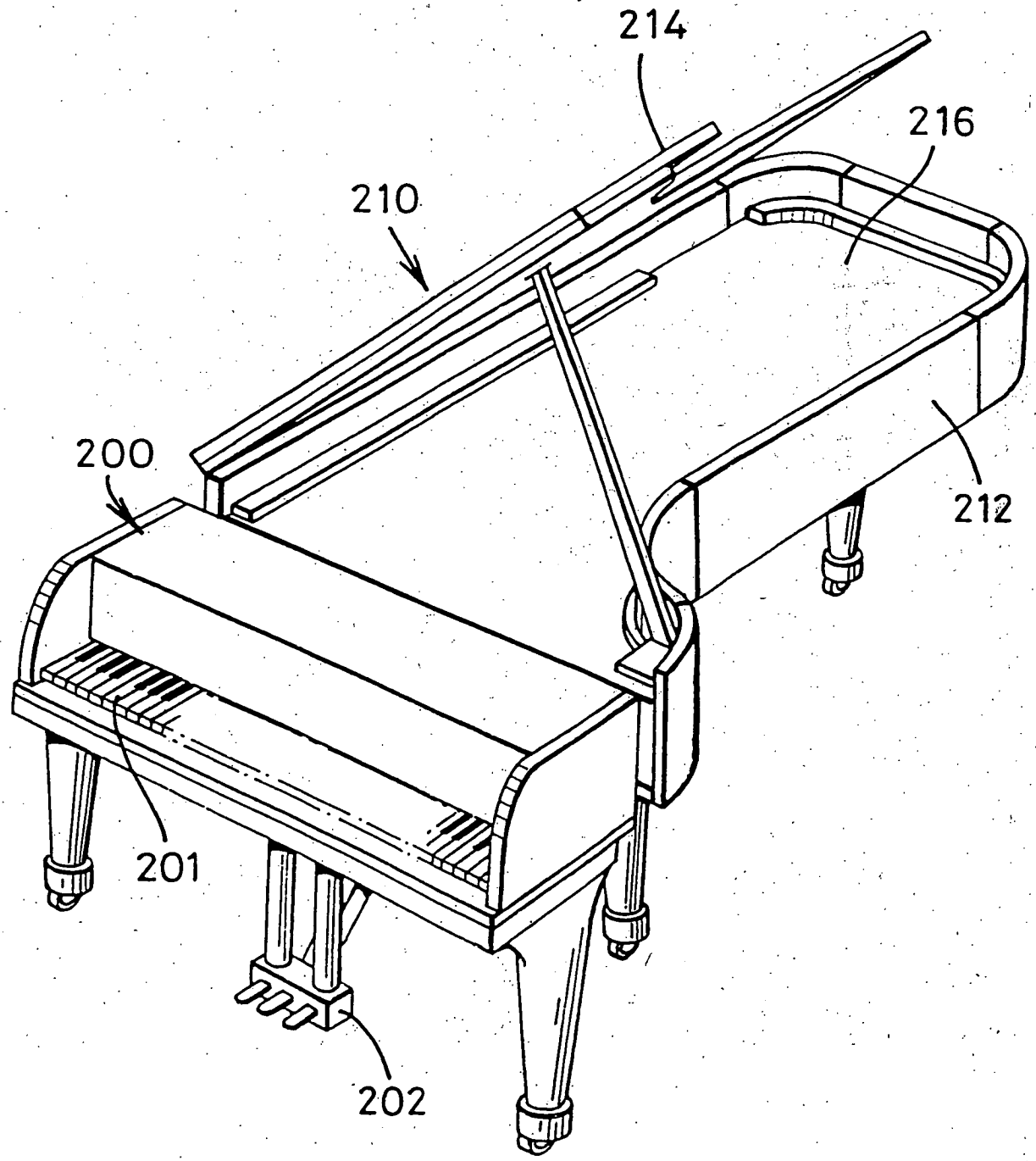


FIG. 9

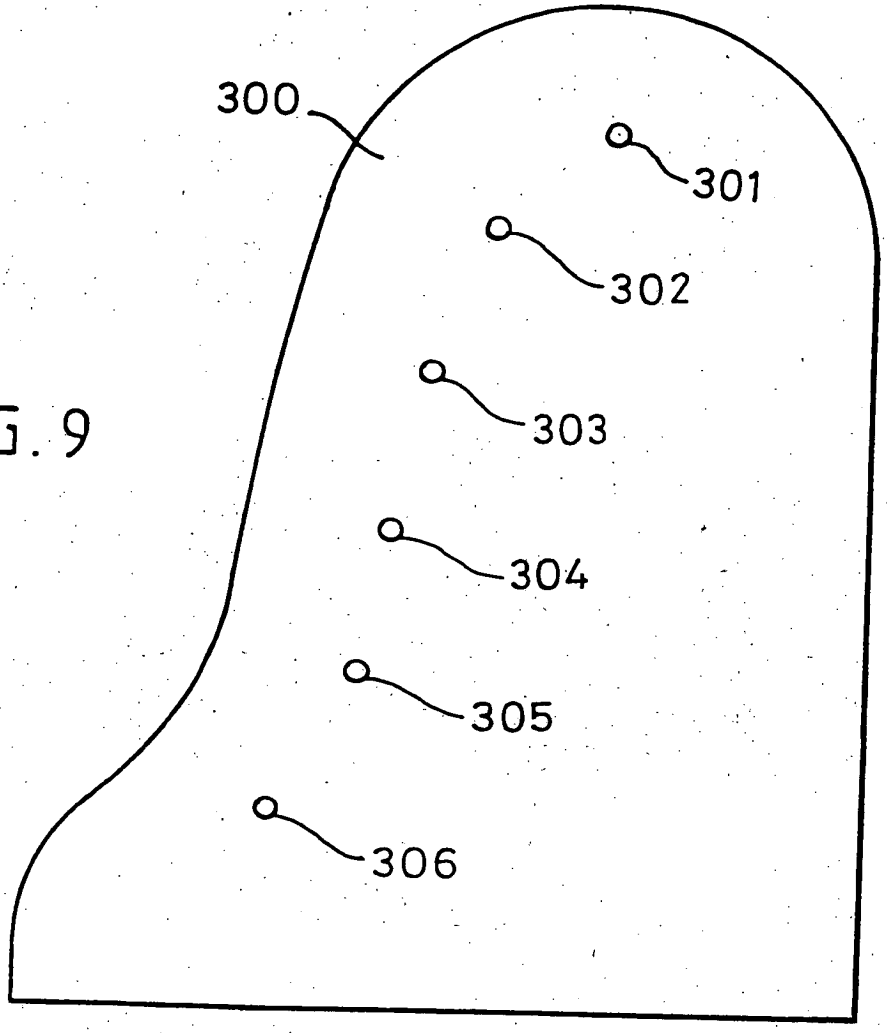


FIG. 10